Estimation and Comparison of China's Provincial Time-Varying Technical Efficiency Incorporating Energy Factor①

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Abstract This paper estimates China's provincial time-varying technical efficiency incorporating energy factor during 1995-2007 with KSS, CSS, BC and DEA model. The research results are as follows: incorporating energy factor or not, the provincial technical efficiency within the sample interval is generally decreasing; after incorporating energy factor, the rank of provincial technical efficiency has changed, the new rank more objectively and accurately reflects the quality of economic growth in different provinces; based on the difference in provincial time-varying technical efficiency and ranks between different models, KSS model has advantages in aspects of time varying and stability.
Key words Energy; Technical efficiency; KSS model; Comparison

1 Introduction

Energy is the material basis for human survival and development, and also necessary production element. Since 2004, China's annual energy consumption is more than 2 billion standard coals and this number keeps increasing. In 2007 and 2008, China's annual energy consumption growth rate was 7.7% and 7.2% respectively, which accounted for 52% and 73% of the world's total amount. China's annual growth rate is not only higher than Japan's (-0.9% and -1.9%), EU's (-2.2% and -0.5%)and other developed countries and regions, but also higher than the world's average level(2.4% and 1.4%).②

Since 2007, as international economy changed, the price of global energy, with oil as representative, changed drastically. It soared up and dropped down in a dramatic cycle, but generally speaking, as the consumption of fossil energy continues, the long-term increase in energy price is a fact. From a macro point of view, the increase in energy price will increase the import cost, enlarge the pressure of China's imported inflation and lead to the net overflow of huge national wealth, which will finally be reflected on the level of domestic output level; From a micro point of view, the increase in energy level and its fluctuation will change the company's production cost and directly affects the profit level and operating efficiency of the company, which further changes the micro technical efficiency. At the same time, the emission of most greenhouse gas comes from the use of energy (UNEP, 2007), so the consumption of energy is closely related to the global climate change and development and the global prospect of low-coal economy.

Since the use of energy is directly and causally related to the emission of greenhouse gas and environmental pollution, the KLEMS international production rate comparison project which is started by Jorgenson and others makes energy element into the analysis framework of production rate. Domestic scholars such as Tu Zhengge (2008), Zhou Jian and Gu Liuliu (2009) also incorporated energy factor when calculating technical efficiency. But, in domestic research on provincial technical efficiency, most articles only cover capital stock, labor and human capital, but not energy factor (such as Yan Pengfei and Wang Bing, 2004; Fu Xiaoxia and Wu Lixue, 2006; Hu Angang et al., 2008). In research method, frontier analysis methods such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis are at the leading position. The most commonly used SFA in China is BC(Battese and Coelli,1992) model.

In this paper, we use KSS model to calculate China's provincial time-varying technical efficiency. Through the analysis and comparison of the estimation and ranking of technical efficiency incorporating energy factor in all provinces, we demonstrate the rationality of incorporating energy factoring provincial technical efficiency research. At the same time, to avoid the error produced by using one single method, we use CSS, BC, KSS and DEA four frontier analysis models to calculate provincial time-varying technical efficiency and compare the estimated results of the four methods.

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② Data comes from "BP World Energy Statistics Yearbook" (2008, 2009).

2 Methodology

2.1 Parametric estimation method of time-varying technical efficiency

A parametric frontier production model that involves time-varying technical efficiency can be formulated as:

$$Y_{it} = X'_{it}\beta + u_{it} + v_{it}, \quad i = 1,...,N, t = 1,...,T \tag{1}$$

In parametric frontier analysis, *Y* and *X* usually mean the output and input variables after logarithmic transformation, *i* means section unit (such as company, household, etc.), *t* means time, v_{it} means random error term, v_{it}~iidN(0,σ_v^2), u_{it} means unexpected random effect term, used to capture the time-varying technical inefficiency of different individual sections. Different scholars proposed a series of u_{it} specification with different time-varying features. Because of the difference in u_{it} specification and estimation methods, a variety of panel data stochastic frontier models of time-varying technical efficiency are formed, such as BC, KSS(Kneip et al. 2003) and CSSW(Cornwell, Schmidt and Sickles, 1990) models. Kumbhakar and Lovell (2000) and other articles have made detailed conclusion of this.

2.2 Non-parametric estimation method of time-varying technical efficiency: DEA

Data envelopment analysis is a non-parametric method based on linear programming. Its basic idea is to use every evaluated unit as a decision making unit (DMU), use DMU's output and input index as variables for evaluation and calculation, determine effective production frontier and decide whether DMU is efficient based on the distance between DMU and effective production frontier. The technical efficiency of output –oriented constant return scale (CRS) can be obtained through solving the following linear programming problem:

$$\begin{aligned} &\max_{\theta,\lambda} \theta \\ &s.t. -\theta y_{it} + Y\lambda \geq 0, \\ &\quad x_{it} - X\lambda \geq 0, \\ &\quad \lambda \geq 0 \end{aligned} \tag{2}$$

θ is a scalar, λ is a(NT×1)constant vector. The DMU *i*'s efficiency at *t* time is TE=1/θ,0≤TE≤1,if TE ＝1,it means that it's located in front of the production frontier and the technique is effective.

3 Empirical Analysis

3.1 Data

Considering the attainability of provincial consumption data, this paper examines the interval of 1995-2007. Since there is a loss data of Tibet, we do not include it within the sample and we combine the data of Chongqing with Sichuan. Thus, in this paper, there is data of technical efficiency of a total of 29 provinces. The variable used in this paper is defined as follow:

Output(*Y*)：represented by provincial GDP. Divide the provincial GDP by provincial GDP deflator, transform it into actual GDP that can represented by constant price 1978＝100. The data comes from "China Statistical Yearbook".

Capital stock(*K*)：uses "perpetual inventory method" to calculate the actual capital stock in all provinces throughout the years, the formula is: $K_{it}=I_{it}+(1-\delta_i)K_{it-1}$, with K_{it} as the capital stock of the year *t* in region *i*. Iitis the investment of year *t* in region *i*,δ_i is the depreciation rate of fixed assets at year *t* in region *i*. The value initial capital stock estimate and depreciation rate δ_i is taken according to the research of Zhang Jun et al.(2004). The provincial capital stock can all be represented by the constant price of 1978.

Labor(L)：according to the process methods of major documents, use the provincial employment number throughout the years to represent labor. The data comes from "CEInet Statistics Database".

Energy(E)：represented by provincial energy consumption throughout the years. The data comes from "China Energy Statistical Yearbook". All the data are converted to standard coal equivalent(SCE). Ningxia and some other provinces have lost some data, which are supplemented through linear interpolation.

The statistical description of all variables is as shown in Table 1.

3.2 The estimation of model and explanation of results

We use the CSSW, BC, KSS and DEA models mentioned above to calculate the provincial technical efficiency with and without energy factor incorporated during the sample intervals, and then we ranked the provincial technical efficiencies of these models. As shown in Figure 1, in order to demonstrate the time-varying features of the provincial technical efficiency during the sample intervals, we draw a figure based on the estimated technical efficiency mean and time. Since the input variables in two conditions are different, so according to principle, their estimates cannot be compared. Here, we mainly examine the relative change of estimated technical efficiency, which leads to the following explanations:

Table 1 The Descriptive Statistics of Variables

	N	T	observations	Mean	Standard deviation	Maximum	Minimum	Unit
Y	29	13	377	1332.3	1288.6	7881.7	47.49	100 million Yuan
K	29	13	377	2769.7	3005.5	20971	133.82	100 million Yuan
L	29	13	377	2233.6	1563.2	6568.1	226	10000 persons
E	29	13	377	6499.5	4657.2	28554	303	10000 tons of SCE

(1)The provincial technical efficiencies in the sample interval generally are decreasing

If energy factor is not incorporated, then based on CSSW,BC,KSS,DEA methods, the provincial technical efficiency estimated means are 0.46,0.58,0.41,0.69 respectively. If energy factor is inclusive, then the means are 0.47,0.58,0.41,0.72. Within the sample interval, based on the four models, all provincial technical efficiencies are decreasing. If energy factor is incorporated, during 1995-2007, based on CSSW,BC,KSS,DEA methods, the annual change rates of provincial technical efficiency are -0.63 %,-0.71%,-0.78%,-0.09% respectively; if energy factor is not incorporated, then within the observation interval, based on these four models, the annual change rates of provincial technical efficiency are -0.66 %,-0.79%,-0.79%,-0.07%. Since technical efficiency reflects the relative distance between all observed values and production frontier. The average decrease in provincial technical efficiencies shows that the distance between observation unit and frontier production unit which represents the best practice is enlarged, which further shows that the difference in the provincial economic growth in this sample interval is increased.

(2)Whether energy factor is incorporated leads to the change in the rank of provincial technical efficiencies

If energy factor is incorporated, then according to the mean of these four technical efficiency estimate ranking, the top five would be Shanghai(1.75), Guangdong(3.75), Fujian(6.5), Jiangsu(6.75)and Hunan(8). These regions have high technical efficiencies. The first four are all Eastern coastal provinces; the last five are Inner Mongolia(23.5), Shanxi(25), Xinjiang(25.25), Ningxia(27.25)and Qinghai(29). These regions have low technical efficiencies and are located in the West. If energy factor is not incorporated, then the first five would be Shanghai(1.75), Guangdong(4), Fujian, (6.25), Hunan (7.75)and Sichuan(8); the last five would be Beijing(22.25), Xinjiang, (22.75)Shanxi(24.25), Ningxia(26.25) and Qinghai(28.75).

It’s easy to see that whether energy is incorporated doesn’t affect the highly efficient Shanghai, Guangdong, Fujian and the poorly efficient Ningxia and Qinghai, but the rank of most provinces is changed regarding energy factor. The provinces whose ranks rose after incorporating energy factor include Jiangsu (+7), Beijing (+3), Guangxi (+3), Hainan (+3), Liaoning (+2), Henan (+2), Zhejiang (+1), Tianjing (+1), Jiangxi (+1), Shanxi (+1), Shandong (+1), which are mostly Eastern provinces; those whose ranks dropped include Heilongjiang (-5), Guizhou (-4), Hebei (-3), Inner Mongolia (-3), Jilin (-2), Sichuan (-1), Hubei (-1), Hunan (-1), Shanxi (-1), Yunnan (-1), Xinjiang (-1), which are mostly Western provinces. We have noticed that the provinces whose ranks rose often have higher energy efficiency[①], so we can say that this change is expected. This change further shows that incorporating energy factories conducive to objectively reflect the element input and output condition of different provinces, but in the new times background where low-coal economy and “Two-type” society construction are in the agenda, incorporating energy factor can more accurately reflect the quality of economic growth in all provinces.

(3)The estimation and ranking of provincial technical efficiencies based on different models have big difference

It’s not hard to find that there is a big difference in technical efficiencies for the same place when using different estimation methods. For example, when including energy, the estimated mean for technical efficiency for Anhui Province when using CSSW, BC,KSS, DEA are (0.5199, 0.7406, 0.4224, 0.9321), and for Fujian, they are (0.5729, 0.8854, 0.4480, 0.9976), and for Gansu, they are (0.2835, 0.4961, 0.2125, 0.5607). Through comparison of the estimated means for technical efficiencies using different methods, we can see that DEA produces the highest value and KSS produces the lowest. At the same time, the two-dimensional figure① of the estimated technical efficiencies of all provinces and time shows that the estimates of CSSW, KSS and DEA models are dramatically different. The time-varying feature of technical efficiencies is very clear. Under comparison, the technical efficiency change margin of provincial technical efficiencies based on BC model is smaller. This result is the compatible with the comparison research result of Sickles (2005) based on Monte Carlo simulation.

Some provinces have big difference in ranking when using different methods. For example, when incorporating energy, Hainan(27, 3, 27, 5), Shandong(4, 19, 4, 18), Beijing(18, 27, 15, 23)and others, and their situations are similar when not incorporating energy. As shown in Table 2, here are the Spearman correlation coefficients of ranks based on CSSW, BC,KSS and DEA incorporating energy factor. The results have shown that CSSW and KSS have the most similar ranking with a correlation coefficient of 0.99. BC and KSS also have a high correlation coefficient 0.94, but the similarity between these "two groups" is not high.

Table 2 Spearman Correlation Test of Technical Efficiency Ranking

	CSSW	BC	KSS	DEA
CSSW	1			
BC	0.5557	1		
KSS	0.9911	0.4867	1	
DEA	0.6473	0.9394	0.5961	1

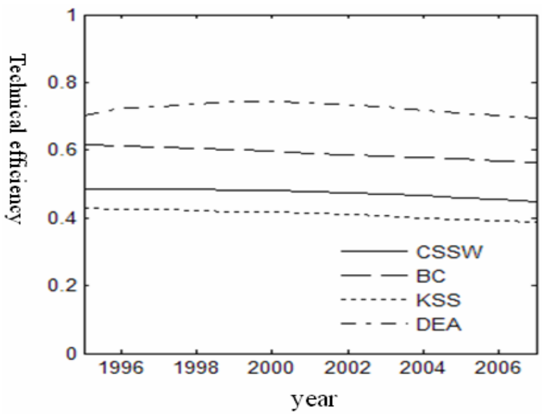

Figure 1 Means for Provincial Technical Efficiencies Incorporating Energy Factor

In order to examine the stability of these four methods, we calculate the technical efficiencies and their rankings incorporating energy factor during 1995~2006 and 1995~2007. The results have shown that CSSW, KSS, DEA models have good stability, with the correlation coefficients of the two time periods 0.9998, 1 and 0.9995. And BC model has a relatively worse stability with a correlation coefficient of 0.9296.

Generally speaking, the difference mentioned above shows that different models have difference in their estimation ideas and technical methods. Sickles (2005) did a comparison research on many semi-parametric, parametric, non-parametric frontier analysis methods which includes CSS, BC, KSS and DEA. The results, which are based on Monte Carlo simulation experiment, show that among all the time-varying models examined, KSS and DEA have the best overall performance. The estimate results of these two models have not only stability but also demonstrate the time-varying feature of technical efficiencies for different individual cross sections. This is mainly because different from CSS and BC, KSS approach removes the presupposed hypothesis of inefficiency from the model, enforces no constraint on the time-varying feature of technical inefficiency term u_{it}, is based on the idea of splice smoothing estimation and principal component analysis, according to estimation calculates a few basis functions from the data, uses their time-varying coefficients to reflect the time-varying effects of individuals, so that it offers a time-varying effect analysis framework that is more common and more inclusive. And the non-parametric DEA method doesn't use the specification of any function, is not restrained from the potential distribution of error term, thus it doesn't really show the unrealistic (Wu, 1996). But since DEA doesn't separate random factors, measurement errors, outliers and statistical noise could all affect the shape and position of production frontiers. In this paper, according to the features of SFA and DEA, we combine the time-varying feature, stability and inclusive of random disturbances of these models and concluded that we prefer KSS among CSS,BC,KSS and DEA four models.

4 Conclusion

This paper has calculated and compared China's provincial time-varying technical efficiency incorporated energy factor with CSSW, BC, KSS and DEA models. The main conclusions are as follow:

Whether energy factor is incorporated or not, the provincial technical efficiencies within the sample intervals are all decreasing. If energy factor is incorporated, during 1995~2007, the annual change rate of provincial technical efficiencies based on CSSW,BC,KSS and DEA models are respectively -0.63 ％,-0.71％,-0.78％,-0.09％, which shows that the difference in economic growth between provinces is enlarged.

When energy factor is incorporated, the ranking for provincial technical efficiency is changed. In the new times background where low-coal economy development and "Two-type" society construction are in the agenda, incorporating energy factor is conducive to more accurately reflect the quality of the economic growth in all provinces.

The estimation and ranking of provincial technical efficiencies based on different models have big difference. According to the calculation of CSSW,BC,KSS and DEA, combing the features of SFA and DEA models, KSS model has advantages in aspects of time-varying, stability and tolerance of random factors.

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